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Bar-driven Transport of Molecular Gas in Spiral Galaxies: Observational Evidence

Kazushi Sakamoto

Nobeyama Radio Observatory, Nagano, 384-1305, Japan

The NRO-OVRO CO imaging survey has provided molecular gas distributions in the centers of 20 nearby spiral galaxies at ~ 300 pc resolution (Sakamoto et al. 1999a). It is found from the survey that central condensations of molecular gas with sub-kpc sizes and 10^8–$10^9 M_\odot$ masses are prevalent in $\sim L^*$ galaxies. Moreover, as shown in Fig. 1, the degree of gas concentration to the central kpc (estimated from comparison with single-dish data) is found to be higher in barred galaxies than in unbarred systems (Sakamoto et al. 1999b). This is the first statistical evidence for the higher central concentration of molecular gas (CO) in barred galaxies, strongly supporting the theory of bar-driven gas transport. To account for the excess gas in barred nuclei, more than half of molecular gas in the central kpc of a barred galaxy must have been transported there from outside by the bar. The time-averaged rate of gas inflow, $\langle \dot{M} \rangle$, is statistically estimated (through the gas consumption rates estimated from Hα and far-IR) to be larger than $0.1 - 1\ M_\odot\ \mathrm{yr}^{-1}$. The degree of gas concentration also helps to test the predictions of bar dissolution and secular morphological evolution induced by bar-driven gas transport (Norman et al 1996; Pfenniger in this volume). Our current data suggest that bar-dissolution times are longer than the consumption times of central gas concentrations in barred galaxies, and thus prefer slow ($t > 10^8 - 10^{10}$ yr) bar-dissolution. A search for non-barred galaxies with high gas concentration, presumably galaxies just after quick bar dissolution, is important to better constrain the bar-dissolution timescale.

There have been a few other lines of observational evidence for the bar-driven gas transport. Table 1 summarizes the pieces of evidence and their prop-

Table 1. Observational evidence for bar-driven gas transport

Method	obs.	evidence Barred gals have ...	stat.	$\dot{M}$	ref.
gas concentration	CO	higher f_{con}	yes	$\langle \dot{M} \rangle$	(1)
central SFR	Hα etc.	higher SFR	yes	no	(2)
metallicity gradient	opt.	shallower gradients	yes	$\langle \dot{M} \rangle$	(3)
dynamical modeling	CO, NIR	net inward gas flow	no (yet)	$\dot{M}$	(4)
obscuration of AGN	X-ray	larger absorption	yes	no	(5)

References: (1) Sakamoto et al. 1999b; (2) Ho et al. 1997 and references therein; (3) Roy 1996 for a review; (4) Quillen et al. 1995, Regan et al. 1997; (5) Maiolino et al. 1999.

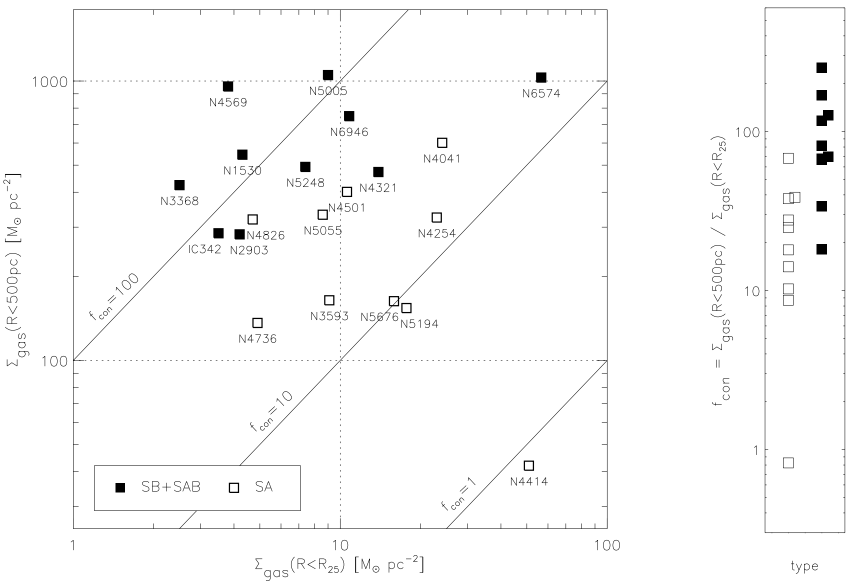

Figure 1. Concentration factor $f_{\rm con} \equiv \Sigma_{\rm gas}\,(R \le 500{\rm pc})\,/\Sigma_{\rm gas}(R \le R_{25})$ measures degree of gas concentration in galaxies. Barred galaxies have higher $f_{\rm con}$ than unbarred counterparts (Sakamoto et al. 1999b).

erties. All of them support bar-driven gas inflow and, though each of them provides different types of information, they are complementary with each other (e.g., some of them are statistical and the others are not, some can give $\langle \dot{M} \rangle$ while others give instantaneous $\dot{M}$). A next step would be to combine these methods, with increasing sample size, in order to construct a sequence of mass transfer, star formation, and morphological changes in galaxies. Galaxy evolution along the Hubble sequence is now within the reach of observational tests.

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References

Ho, L. C., Filippenko, A. V., & Sargent, W. L. W. 1997, ApJ, 487, 591

Maiolino, R. Risaliti, G., Salvati, M. 1999, A&A, 341, L35

Norman, C., Sellwood, J. A., & Hasan, H. 1996, ApJ, 462, 114

Quillen, A. C. et al. 1995, ApJ, 441, 549

Regan, M. W., Vogel, S. N., & Teuben, P. J. 1997, ApJ, 482, L143

Roy, J. -R. 1996, ASP Conf. Ser. 91, 63

Sakamoto, K., Okumura, S., Ishizuki, S., & Scoville, N. Z. 1999a, ApJS, (Oct. issue) in press

Sakamoto, K., Okumura, S., Ishizuki, S., & Scoville, N. Z. 1999b, ApJ, (Nov. 10 issue) in press, (astro-ph/9906454)